



Economic Values Associated with Construction of Oyster Reefs by the Corps of Engineers

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PURPOSE: This technical note is intended to accompany the Community Model Template constructed under the Ecosystem Management and Restoration Research Program. That template includes a community model for the American oyster (*Crassostrea virginica*) which can be used to quantify the ecological benefits of an oyster reef in an ecosystem restoration project. This technical note describes additional benefits to consider in planning a restoration project.

INTRODUCTION: Oyster reef restoration has become an important component of coastal District projects at U.S. Army Corps of Engineers (USACE) Districts. Reefs provide both ecological and economic benefits. Ecological benefits result from the water quality, erosion prevention and stabilization, and habitat services provided by the reefs (Wilber 2002). Economic benefits result from the economic services provided by oyster reefs, and are related to the harvest of oysters, fish, and crab from the reefs or adjacent areas, increased recreational use from cleaner water, and cost savings for bank stabilization and dredged material disposal. Local sponsors and stakeholders often express an interest in the economic value of oyster harvest, but other economic values should also be considered, along with the ecological benefits. The intent of this report is to provide information to Corps planners on the economic benefits provided by oyster reef restoration, so that the full range of benefits can be considered when planning and evaluating oyster restoration projects. Benefits may occur at the project site or accrue within the watershed or beyond. It is the responsibility of the Corps to make an effort to account for all of the ecological and economic benefits resulting from restoration efforts, monetary and non-monetary (U.S. Army Corps of Engineers 2000).

The economic services reviewed in this paper are water quality, commercial harvest, recreation (fishing, swimming, boating), and erosion protection and bottom stabilization—provided by oyster reefs. This information provides the basis for including monetary considerations in evaluating Corps oyster restoration projects.



Figure 1. Near-shore oyster reefs (Norfolk District)

Oyster populations are efficient in filtering phytoplankton, pollutants, and suspended sediment from the water column, filtering about a gallon and a half of water per hour (U.S. Army Engineer District, Wilmington 2002). Oyster reefs provide a stable substrate for attachment of sponges, sea whips, tunicates, and bryozoans, which with accumulating live oysters result in a complex structural habitat for benthos and fish.¹ The structural relief in the water of the oyster reef can dissipate wave energy, acting as a breakwater, stabilizing bottom sediments and reducing erosion. These improved conditions lead to increased use for recreation.

The spatial extent for considering economic benefits for an oyster reef extends to adjacent reefs, near shore and even watershed areas. Improvements in water quality arising from the oyster beds affect the water quality for a wide area, dependent on circulation and flow patterns, to a much larger extent than the hectares or acres constructed. Filtering by oysters may increase the water quality benefits resulting from other management actions—wastewater treatment, land use changes, and nonpoint pollution controls. Valuation of improved water quality for oysters alone would be difficult, without considering interaction with other management actions. In the same way, habitat, erosion protection, and recreation benefits provided by the reefs extend across the system, and support other management actions.

The economic value of oyster reefs consists of the potential market value of the harvested oysters and the value of the water quality, recreation, and erosion protection and stabilization services. Oyster prices can be used directly to evaluate proposed oyster reef projects. Recreation use increases after water quality is improved, making recreational fishing and adjacent beach use more attractive (Bockstael et al. 1989; Hayes et al. 1992). Recreation values from overall improved water quality have been estimated by travel cost and contingent valuation methods.

ECONOMIC BENEFITS AND COSTS OF OYSTER REEFS FOR OYSTER PRODUCTION:

Oyster reefs fit well as components of Corps coastal designs and plans. Constructed oyster reefs are included as design features of large, e.g., Chesapeake Bay, and small restoration projects, as components in Section 204 and Section 206 projects, and as part of



Figure 2. Oyster harvest, North Carolina (North Carolina Division of Marine Fisheries)

mitigation plans for navigation projects. Oyster reefs provide structural diversity and perform ecological functions that increase or are in addition to the functions of other restoration components. Use of oyster reefs has been shown to have a relatively low marginal cost compared to marsh or sea grass restoration with comparable high marginal ecological benefits.¹ Where their growth is abundant and the waters are suitable for consumption, oysters support an important commercial and recreational fishery. Due to their economic and cultural value, oysters are considered an important component of the coastal heritage in those areas.

¹ Personal Communication. 2003. C. R. Wilson, U.S. Army Engineer District, Wilmington, NC.

Interest in oyster harvest values is often high with stakeholders and local sponsors due to the prominence of shellfishing and states' responsibilities for management of coastal commercial fishing permits. The Corps' Chesapeake Bay oyster restoration projects were analyzed to compare the value of the harvested oysters to the costs of constructing the oyster reefs. This analysis shows that the number of years required to recover initial costs is high for normal productivity and price levels.¹ Maryland and Virginia both construct oyster reefs in the Bay using base material of oyster shell. Virginia reefs are constructed with oyster shell as base material, costing about \$10,000 an acre (Table 1). The Maryland reefs are similarly constructed but are seeded with broodstock. Costs of broodstock are \$10,000 an acre, making initial construction of \$20,000 an acre for Maryland. Additionally, Maryland reefs are maintained annually by addition of broodstock and more shell base material, creating a "put and take" fishery; the Virginia reefs are not seeded or maintained annually.¹

Table 1	
Construction Costs and Oyster Production for Chesapeake Bay Oyster Reefs	
Construction	
Shell Base Materials	\$10,000/acre
Initial Stocking Costs	\$10,000-20,000/acre
Broodstocking	
Broodstocking Rates	100,000-200,000 oysters/acre
Costs	\$0.01/oyster
Costs to Broodstock	\$20,000/acre
Oyster Production	
Pounds of Oyster Meat/Bushel	7
Price of Oyster Meat/Pound	\$3.13

Oyster habitat quality is affected by a number of physical factors—water depth, dissolved oxygen, salinity, proximity to other reefs—and biological variables, such as the presence of living oysters on the reef (Wilber 2002). The addition of maintenance broodstock for Maryland reefs (creating a "put and take" fishery) results in higher productivity—averaging 100 bushels/acre/year—while the Virginia reefs produce an average of less than 20 bushels/acre/year. The seeding and maintenance of the Maryland reefs improve productivity, but at an increased cost. Harvesting has the effect of damaging the reef and prevents the aging of the oyster populations, reducing or reversing ecological benefits, and reducing the lifespan for a constructed reef. Creation of unharvested oyster reefs (sanctuary reefs) in proximity to harvested areas enhances the populations of harvested reefs (Wilber 2002). Maintenance of the reefs and lack of disturbance from harvesting increases the reef lifespan and creates habitat diversity through development of maturing reefs, with oysters at varying ages and a more complex structure.

The market price of oysters and construction costs (Table 1) were used in an analysis by Schulte¹ to determine the years required to recover the initial construction costs, using differing annual productivities (6 to 200 bushels per acre) (Tables 2 and 3). Schulte's evaluation looked at the Virginia construction (without broodstock maintenance) (Table 2) and the Maryland construction approach (Table 3). Evaluating oyster reefs on harvest value alone, for oyster reefs without stocking, at the 100-bushel productivity level, as in Virginia, it would take 14 years to recover costs, with a benefit to initial cost ratio of 0.07 (Table 2). For the "put and take" maintenance approach, it would take 5 years of 100 bushels per year productivity to recover initial costs, with a benefit to initial cost ratio of 0.22 (Table 3).

¹ Personal Communication. 2003. "Benefit cost analysis of oyster reef construction, Chesapeake Bay," D. Schulte, U.S. Army Engineer District, Norfolk, VA.

Table 2 Summary of Recovery of Initial Cost Information for Reef Construction Without Annual Maintenance (Virginia Method)			
Bushels Harvested/ Acre	Benefits/Acre	Years to Recover Initial Cost	Benefit to Initial Cost Ratio
6	\$ 133	225	0.00
20	\$ 442	68	0.01
50	\$1,106	27	0.04
100	\$2,212	14	0.07
200	\$4,424	7	0.15

Table 3 Summary of Recovery of Initial Cost Information for Reef Construction With Annual Oyster Reseeding (Maryland Method)			
Bushels Harvested/ Acre	Benefits/Acre	Years to Recover Initial Cost	Benefit to Initial Cost Ratio
6	\$ 133	75	0.01
20	\$ 442	23	0.04
50	\$1,106	9	0.11
100	\$2,212	5	0.22
200	\$4,424	2	0.44

Schulte's analysis is based on current oyster harvest conditions and market prices, and productivity of oysters, and these could change, e.g., increased market prices, disease-resistant oysters. However, it is highly unlikely oyster price and cost conditions would change enough to raise the very low benefit to initial cost ratios significantly. The oyster harvest values as analyzed by Schulte must be considered along with other values. "Restoration of oyster reefs should not be viewed solely or even primarily as an oyster fisheries issue" (Frankenberg 1995). Oyster reefs help to structure the estuarine ecosystem, providing water quality, recreation, erosion protection and habitat services upon which all users of the coastal zone rely.

Oyster Reef Impacts on Harvest of Fish and Crabs. The structure provided by oyster reefs serves as habitat for other commercially important species of fish and crab. A study in North Carolina (West Bay, Neuse River) compared the value of fish and crab from three oyster reefs to the value of harvest from adjacent unstructured sand bottom areas (North Carolina Sea Grant 1997). The long-term commercial value of fish and crabs was greater than the value of the oyster production. At another North Carolina site (Ocracoke Island), the value of fish caught on restored reefs was equal to the value of fish caught on natural reefs. These North Carolina results suggest that the greatest economic value of restored oyster reefs is as habitat for commercial fish and crabs, rather than for oysters.

To evaluate the economic benefit of oyster reefs for fish and crabs requires determining the marginal value added to the harvest value of fish and crabs, which can be attributed to the reefs. Also, it is necessary to determine whether the fish and crabs caught at the restoration reefs would have been caught at another location, or alternately, whether the biomass represents an additional marine biomass yield. In the latter case, the reefs would have more value, because the additional yield of fish and crabs would not have been produced without construction of the reefs.

RECREATION: Freeman (1995) reviewed studies of valuation of water quality improvement and marine recreation, finding that value per trip and annual values varied with type of economic model, location, and target species. Economic benefits of recreation resulting from improved water quality were estimated using recreation demand and travel cost models for the Chesapeake Bay and using contingent valuation models for Chesapeake Bay and Upper Narragansett Bay, Rhode Island.

The Chesapeake Bay models used recreation demand relationships between measures of existing water quality and characteristics of the Chesapeake recreation sites and recreators (e.g., equipment ownership). The recreation demand models established demand relationships, and predicted the recreation use for improved water quality, assuming that a percentage improvement in water quality would result in an equal percentage change in days fishing, boating, and swimming (Bockstael et al. 1989).

The contingent value approaches directly asked respondents' willingness to pay in taxes for "water that is acceptable for swimming and other activities" in the Chesapeake Bay (Bockstael et al. 1989), and "for improvements in water quality that allows for shellfishing and is safe for swimming" in Upper Narragansett Bay (Hayes et al. 1992).

Fishing. Economic benefits for marine fishing fall in the \$13 to \$135 per trip (2003 dollars) range depending on the species and location (Gulf of Mexico, Atlantic, Pacific). Annual per person values range from \$135 to \$1,347 (2003 dollars), depending on the extent of the market area, species available at the site, size, location, and the valuation method used (Freeman 1995). Contingent valuation models produced higher values than the user-based travel cost models developed from observed recreation behavior.

In the Chesapeake Bay, Bockstael et al. (1989) developed a demand model for fishing and used the travel cost method to calculate benefits for striped bass fishing; striped bass are often associated with oyster reefs (Wilbur 2002). The demand models were developed using data from the 1980 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, pulling out the Chesapeake Bay respondents. The demand equation for bass fishing days was developed using catch rates, type of equipment (inboard or outboard motor), and recreational budget, to predict striped bass fishing days. The fishing days were used in the travel cost model to estimate benefits. Using the demand equation, Bockstael et al. (1989) estimated change in fishing days for a 20-percent improvement in catch rates, i.e., a 20-percent increase in number of fish caught per trip. The results of the survey were expanded to the population of black bass anglers, and the benefits of improved water quality for black bass fishing were calculated at \$2.3 M (2003 dollars).

A contingent valuation model was used to estimate benefits to shellfishing for improvements to the water quality of Upper Narragansett Bay (265 km², 102 mi²), after costly expenditures for infrastructure to reduce pollution by Rhode Island communities (Hayes et al. 1992). Respondents were asked their willingness to pay for acceptable swimming and shellfishing. Versions of the survey asked for swimming and shellfishing separately or combined. Willingness to pay for water suitable for consumption of shellfish ranged between \$9 M and \$92 M (2003 dollars) annually, depending on whether a payment vehicle, i.e., pay through a tax, was specified.

For fishing in waters off Louisiana, the benefits of being able to fish over oyster reefs were determined from marine anglers who fish over oyster beds. The oyster bed users were identified from anglers that were sampled in the Marine Recreational Fish Statistics Survey, performed annually by National Marine Fisheries Service. Asked their willingness to pay to maintain the right to fish over oyster reefs, the anglers had an average annual value of \$13.21 (2003 dollars) per angler.

Approximately 23 percent of the annual marine fishing days occur over oyster beds, resulting in an estimated \$2 M in benefits for Louisiana coastal waters.¹

Boating. Changes in boating as a result of improved water quality were evaluated for the Chesapeake Bay, using demand equations for boaters developed from a 1983 survey of boaters from Maryland. The demand equation used responses from boaters who trailered their boats and excluded boaters using a marina (cannot choose a destination once a marina is selected). Demand equations for 12 county sites were developed using access costs to the site, costs to the closest substitute site, and the value of the boat (Bockstael et al. 1989). The benefit estimate for a 20-percent improvement in water quality is \$8 M (2003 dollars).

Beach Use and Swimming. Oyster reefs improve beach and swimming use by improving the water quality conditions through filtering out phytoplankton and fine sediment from the water column. In cases such as the Chesapeake and Upper Narragansett Bays, the major pollutants were nonpoint runoff and wastewater discharges. Improvement or construction of new treatment facilities and nonpoint controls significantly reduced the pollutant loadings in the bays, so that the water reaching the oyster beds has improved levels of biological oxygen demand, phosphorous, and nitrogen to support aquatic life. The oysters further improve the water quality by reducing the phytoplankton and sediment. These effects make the water clearer, removing the green tint of the phytoplankton, improving the desirability for swimming and water contact activities.



Figure 3. Oyster reefs, Army Reserve Center Mitigation Project, Morehead City, NC, Wilmington District

Valuation of pollutant reduction for swimming and beach use has shown low per person values, and different values for essentially the same effect. A value of \$7.20 per person per year (2003 dollars) was estimated for a 10-percent reduction in oil, total bacteria, and color. A similar study had a much higher value—\$23.39—for the same 10-percent reduction in pollution by oil, fecal coliform bacteria, and chemical oxygen demand (Freeman 1995).

For larger systems serving population centers, with awareness of pollution problems, the public can estimate their willingness to pay for “swimmable water” or “open beaches.” Aggregate, rather than per person values were developed using travel cost demand models and contingent valuation models for the Chesapeake and contingent valuation for the Upper Narragansett Bay.

Surveys at 11 western shore Maryland beaches were used to develop beach use demand models for Chesapeake Bay. Demand for the different beaches used access to the beach, costs to a substitute beach, and ownership of recreation equipment (boat, recreational vehicle, swimming pool) to predict demand. Using the demand models, a 20-percent increase in swimming was evaluated, assuming a

¹ Personal Communication. 2003. “Evaluating economic benefits of oyster reefs to recreational fishing in Louisiana,” J. Isaacs, Louisiana Department of Wildlife and Fisheries, Baton Rouge, LA.

20-percent decrease in nitrogen and phosphorous. Mean (midrange) estimates of benefits for beach use were \$56 M (2003 dollars) (Bockstael et al. 1989).

For previously highly polluted systems such as the Chesapeake and the Upper Narragansett, where beach closings due to pollution were common, the hypothetical nature of the contingent valuation approach is not a limit; beach closures and swimming bans actually happened. The populations of Washington, DC, and Baltimore were surveyed by phone to ask willingness to accept a tax increase “to raise Chesapeake Bay water quality from a level unacceptable to a level acceptable for swimming and/or other related activities.” The phone survey was able to reach those who did not use the Chesapeake, as well as users. Average benefits were \$109 M for users and \$38 M for non-users of the Chesapeake, for a total of \$147 M (2003 dollars).

The Narragansett Bay contingent value study asked specifically about swimming, and willingness to pay ranged from \$68 M to \$104 M (2003 dollars). The range is due to different versions of the survey (tax specified as payment or unspecified vehicle, combining swimming and shellfishing) being used.

EROSION PROTECTION AND BOTTOM SEDIMENT STABILIZATION:

The physical presence of an oyster reef is a stabilizing force on the mobile and unconsolidated bottom sediments found in tidal and subtidal environments (Wilber 2002). The deflection of waves and wave energies protects shorelines and inland waters from erosive forces, and promotes sedimentation and establishment of submerged aquatic vegetation. In cases of nurseries or other sensitive areas, oyster reefs may provide protection from erosion and protect near-shore, shoreline, and upland areas. The economic benefit of an oyster reef for shoreline protection or sediment stabilization is determined by comparing the cost of constructing the oyster reef to the cost of the structural or non-structural management measure that would provide the same level of protection services. These services have not been valued in the literature. One study did relate the loss of a stabilized shoreline to a decrease in property values (Johnston et al. 2002).



Figure 4. Roanoke Island Festival Park, Sec. Project, Manteo, NC, Wilmington District

HABITAT: Oyster reefs provide substantial habitat to a large assemblage of benthic organisms and fish. Older, maturing reefs become larger and more complex, and provide greater habitat diversity. The extensive irregular surfaces of a reef provide 50 times the surface area of a similar sized flat bottom. These crevices provide good nursery habitat for a wide diversity of vertebrate and invertebrate organisms—worms, snails, sea squirts, sponges, crabs, and fishes.¹ The fish that use the reef eat smaller fish or the many small benthic crustaceans or mussels. The reefs provide protective

¹ Personal Communication. 2003. C. R. Wilson, U.S. Army Engineer District, Wilmington, NC.

habitat for mating crabs (North Carolina Sea Grant 1997). These habitat services have not been valued in the literature, and assessment of habitat values of oyster reefs would require an ecological approach, acknowledging the connectedness of the reef habitat to the fish, benthos, other shellfish of adjacent reefs, bottom sediments, and shoreline areas.

COSTS OF OYSTER REEF SERVICES:

The discussion of water quality benefits emphasized the nature of those benefits, i.e., the oyster reefs support water quality management measures and structures that occur throughout the region drained by the estuary with the oyster reefs. These costs can be substantial and are difficult to fully account for because they are borne by public entities, e.g., costs of wastewater treatment plants, and by the private sector, e.g., costs of regulations on treatment of feedlot runoff. One impetus behind the Narragansett Bay study was to comprehensively evaluate total benefits of water quality improvements, after approval of a \$35 M bond issue for Rhode Island communities for treatment facilities (Hayes et al. 1992). Additionally the opportunity costs (e.g., spending public monies for other purposes) and secondary and higher order costs are impossible to completely track, i.e., the total costs are not known for the benefits provided. For these reasons, a strict benefit cost analysis is not possible.



Figure 5. Oyster reef construction (Norfolk District)

SUBSTITUTES FOR OYSTER REEF SERVICES: The services provided by oyster reefs can be monetized, some readily, some with great difficulty and uncertainty (Johnston et al. 2002), using nonmarket and market techniques. Where data are unavailable, an approach is to ask “if the oyster reefs weren’t there, are there structures or other ways to provide the same services the reefs perform?” and “what is the cost of providing the substitute?” The cost of substitutes for providing the services can be used to determine the value of the oyster reefs. This is the approach discussed above for erosion protection, comparing the cost of oyster reef to the cost of an alternative method to obtain the same level of services. Of the services discussed above, only the costs for construction of oyster reefs for harvest have been identified (Table 4). Possible substitutes are identified for water quality, habitat, and erosion protection services.

Table 4		
Possible Substitutes for Oyster Reef Services		
Services	Functions	Substitutes
Oyster Harvest	Shellfish Production	\$10K per acre unstocked \$30K per acre stocked
Water Quality	Phytoplankton and Sediment Filtering	Marine algacide and marine sediment retention structures possible
Habitat	Habitat Structure	Artificial habitat structure possible
Erosion Protection and Sediment Stabilization	Erosion Protection, Stabilization	Breakwater and sedimentation structures

SUMMARY: Oyster reefs provide services of economic value through oyster production and water quality, habitat, and erosion protection services. Evaluations of oyster reef restoration projects are made on a case by case basis, taking into consideration the full range of ecological and economic benefits of a project. The information provided in this technical note on the valuation of water quality, recreation, erosion protection, and habitat services provided by oyster reefs should be used to identify potential benefits. Monetization of the benefits may be desirable in some cases, using methods identified. Of these services, oyster production has been evaluated in an analysis of the recovery of initial costs¹ for Chesapeake Bay reef construction. Construction of oyster reefs intended for non-harvest, sanctuary reefs, would enhance the oyster production of adjacent oyster reefs (Wilbur 2002), and increase the harvest of other commercially important species (North Carolina Sea Grant 1997). The sanctuary reefs provide water quality, recreation, erosion protection, and habitat and enable development of complex and diverse habitats.

The most substantial economic benefits from oyster reefs may result from harvest of other commercial species and water quality improvements. As pointed out, the phytoplankton and suspended sediment filtering clarify the water, increasing recreation conditions for swimming, beach use, and boating. The water quality and habitat quality services result in increased sport fishing.

Public interests in shellfish and estuarine restoration will likely ensure that the Corps will continue to construct oyster reefs. Decisions on oyster reef projects should include the range of benefits resulting from Corps actions. This may require expanding the evaluation to those areas that provide inflow or affect the oyster bed project site, and for which the oyster beds affect the water quality or other services. Monetization of benefits may be desirable, requiring data collection and methods beyond the scope of this technical note.

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¹ Personal Communication. 2003. "Benefit cost analysis of oyster reef construction, Chesapeake Bay," D. Schulte, U.S. Army Engineer District, Norfolk, VA.

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